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TODS BioCast User Manual

Forecasting 3D Satellite Derived Optical Properties Using Eulerian Advection Procedure

Version 1.0

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14. ABSTRACT

BioCast is a software package designed to forecast the surface bio-optical components of the ocean. This software is a single component of the Tactical Oceanographic Data System (TODS) delivered to the Naval Oceanographic Office. BioCast is an automated system for producing forecasts of oceanic bio-optical properties. It produces hourly forecasts up to n hours by coupling Automated Optical Processing System (AOPS) produced bio-optical products with Navy Coastal Ocean Model (NCOM) ocean current products to predict how the current models will affect the future optical environment. The system is designed to be easily configured and to run in an automated fashion. This document describes the theoretical background of the forecasting technique as well as the configuration and operation of the system.

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Executive Summary

The Bio-Optical Forecasting (BioCast) system is an automated software package designed to produce a forecast of Automated Optical Processing System (AOPS)-rendered bio-optical products. BioCast can produce hourly forecasts of up to 48 hours. BioCast works by coupling the AOPS-produced bio-optical products with Navy Coastal Ocean Model (NCOM) modeled ocean currents to produce an "advected" optical product forecast. Each forecast is a three-dimensional field of the bio-optical product covering the region of interest defined by the AOPS input file.

BioCast is designed to apply a simple advection approach to satellite derived products in order to forecast the surface optical properties. This approach assumes the bio-optical properties are controlled solely by the physical circulation fields within a 48 hour cycle. The bio-optical processes such as phytoplankton growth and decay, or CDOM production and oxidation are not considered in the initial version of BioCast. This "passive tracer" approach is reasonable for a 24- or 48-hour forecast so long as an initial bio-optical property field from AOPS is provided.

The BioCast system uses an Eulerian advection procedure to calculate the fluxes affecting each model grid cell. The horizontal fluxes are calculated directly from the modeled two dimensional current fields. The vertical fluxes are estimated from the horizontal fields via continuity. The system is designed to run iteratively so that each new forecast cycle is updated with the latest available satellite information. The system is computationally inexpensive and does not require numerical integration with the physical circulation model codes. These features make the system an efficient and practical solution to the ocean optical forecasting problem.

Introduction

Work completed under the *Modeling, Sensing and Forecasting Ocean Optical Products for Navy* project provides naval operations with new and enhanced predictive capabilities for the Tactical Ocean Data System (TODS) implemented at NAVOCEANO. TODS provides fusion of satellite imagery, METOC models and *in situ* observation products (i.e. gliders) that is subsequently coupled to Navy performance models to produce target and/or asset performance surfaces. The system components (*Display, OpCast/BioCast, 3DOG, and MIW System Performance Surfaces*) provide both real time and forecast characterizations of two and/or three dimensional battlespace used to produce warfare performance surfaces depicting ocean optical and physical properties as well as visible target detection. TODS currently produces:

1. the performance surface for the MIW underwater laser imaging systems (AN/AQS-24) and airborne systems (ALMDS)
2. the swimmer performance surface for underwater diver visibility and diver vulnerability for MIW and EXW missions
3. the performance surface for deployment of active and passive EO bathymetry systems (CHARTS and Passive EO satellite systems)

Previous transitions from this project include the TODS *Display*, *LAGER* – quality control software for glider optics data, and *OpCast*, a two dimensional optical forecast model. The transitioning element described in this document is *BioCast,* a three dimensional optical forecast model, which maintains the ability to generate two dimensional optical outputs.
Future transitions will include the 3D Optical Generator (3DOG) which produces 3D optical volumes that feed the BioCast v2.0, and the AQS-24 performance surface model.

This document provides the technical basis to transition BioCast version 1.0 and its improvement over the previously delivered OpCast to the NP3 Ocean Optics branch of the Naval Oceanographic Office (NAVOCEANO).

System Description

BioCast is an automated system for producing forecasts of oceanic bio-optical properties. It produces hourly forecasts up to *n* hours by coupling Automated Optical Processing System (AOPS) produced bio-optical products with Navy Coastal Ocean Model (NCOM) ocean current products to predict how the current models will affect the future optical environment. Currently, each forecast is a two-dimensional field representing the bio-optical properties of the region of interest defined by the AOPS input file. BioCast is designed to solve for the three-dimensional advection-diffusion-reaction (ADR) of dissolved or particulate tracers *(*biological or chemical materials*)* in aquatic environments. It requires a set of flow fields *(*North/South and East/West velocity components*)*, bathymetric data, an initial property field of the parameter of interest, and a user-specified spatial grid. The advantage of BioCast is that it rapidly solves the ADR of tracers significantly faster than fully explicit coupling with an ocean circulation model. The computational savings is very attractive for a wide range of forecasting applications and basic oceanographic/aquatic research programs.

A conceptual overview of forecasting the distribution of bio-optical properties using BioCast is provided in Figure 1. In this example, satellite imagery representing the beam attenuation

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coefficient ($_c$) at 531nm is combined with the flow fields generated by the NCOM model. The initial "Seed" image (i.e. representing today's beam-c field) is combined with today's NCOM hourly forecast currents to predict the turbidity distribution ($_c$)[1] in 24 hours. The following day's satellite beam-c image is compared with the forecast to determine the uncertainty or difference. The software is designed to run daily in automated fashion, providing a new capability for navy METOC operations by extending the utility of operational satellite image products. Additionally, the model evaluation uses the next day satellite image to provide a "self-checking" or reliability index of the forecast product.

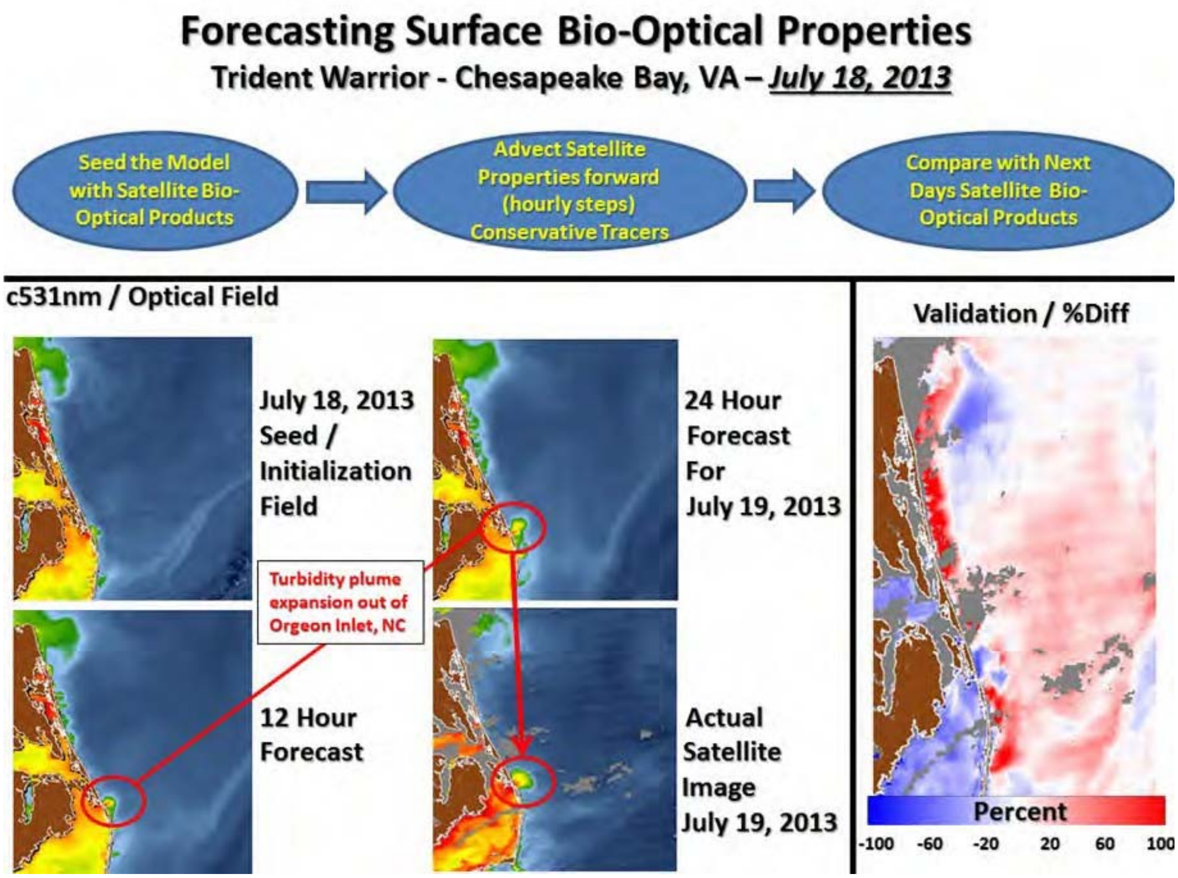

Figure 1: Examples of BioCast processing for Chesapeake Bay, Virginia during the Trident Warrior exercise using the MODIS satellite product for beam attenuation (proxy for turbidity) coupled with the currents derived from the NCOM. BioCast enables the currents to advect the turbidity pixel information, generating a picture of future turbidity distribution. Differencing the BioCast product from the actual next day's image provides insight into the uncertainty of the BioCast model.

[1] The turbidity concentration represented by optical beam attenuation coefficient ($_c$) is used in this example; however, other optical products could be used.

System Requirements

The BioCast software produces a prediction of optical conditions in all parts of an area of interest. It is designed to run on the Linux operating system, requiring a UNIX-like environment with the availability of shell scripts, command line utilities, and a cron scheduling system. The system is built around a framework of shell scripts which provide a high-level interface to the low-level functionality provided by binary executables written in *C* and Fortran. Users should be familiar with UNIX; BASH shell programming; and remote sensing, particularly regarding computer processing of satellite data, and ocean modeling.

Configuration of the system is accomplished by setting environment variables in "area" scripts. By setting the appropriate environment variables, every aspect of the operation of the BioCast system is controlled.

Data Input

BioCast requires data inputs from two primary sources, AOPS bio-optical products and relocatable NCOM current fields (COARDS compliant NetCDF format). In situ data acquired from ocean gliders or Battle Space Profiler (BSP/AEP) greatly enhance the forecasting capability by allowing expansion to three dimensional modeling[2].

Specific inputs include:

1. satellite ocean color imagery: MODIS-Terra, MODIS-Aqua, VIIRS
2. numerical models: relocatable NCOM (NCOM-RELO)
3. in situ data: physical and optical glider data[3] and BSP/AEP data

Satellite Ocean Color Imagery: AOPS Bio-Optical Products

The bio-optical product for BioCast is produced by the Automated Optical Processing System (AOPS) v4.2 or later and is in the native Hierarchical Data Format (HDF)[4] produced by that system (Martinolich, 2006), examples of the AOPS output are given in Figure 2 and Figure 3. AOPS automatically handles all stages of calibration, atmospheric correction, application of oceanographic algorithms, warping to a geographic area of interest, compositing, and creation of quick look browse images. The geographic coverage area and spatial resolution are defined by attributes within the AOPS HDF file and the subsequent forecast is performed on this grid. BioCast can produce a forecast for any environmental parameter that AOPS can generate such as: total absorption (a), backscattering (b_b), chlorophyll (chl), sea surface temperature (SST), diver visibility, etc.

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[2] Optimization of the three dimensional capability is beyond the scope of this transition however it will be addressed in the transition of the 3-Dimensional Optical volume Generator (3DOG) component of the Tactical Ocean Data System (TODS) project.

[3] quality controlled with LAGER – transitioned FY2011

[4] An intermediate stage exists in the BioCast data processing flow to convert the HDF files produced by AOPS into NetCDF, since BioCast can only read NetCDF formatted files; however, this conversion is performed automatically as needed by the BioCast system.

The advection software in BioCast requires a completely filled-in image to initiate advection, as seen in Figure 4. As BioCast cannot advect empty pixels in a satellite image, once an image is chosen, a script is executed to generate a "seed" image that is completely filled in. The seed is created using the previous day's forecast if the environment variable is set for the directory location of forecast outputs. If the forecast directory is not set, then the seed is generated using a limited iterative nearest neighbor triangular interpolation procedure (Casey, et. al., 2007). The first stage starts with the imagery from the target day and determines if the forecast directory is set. If set, then the contaminated pixels in today's image is filled with yesterday's forecast. If the forecast directory environment variable is not set, then the limited triangular interpolation technique is used to fill in image.

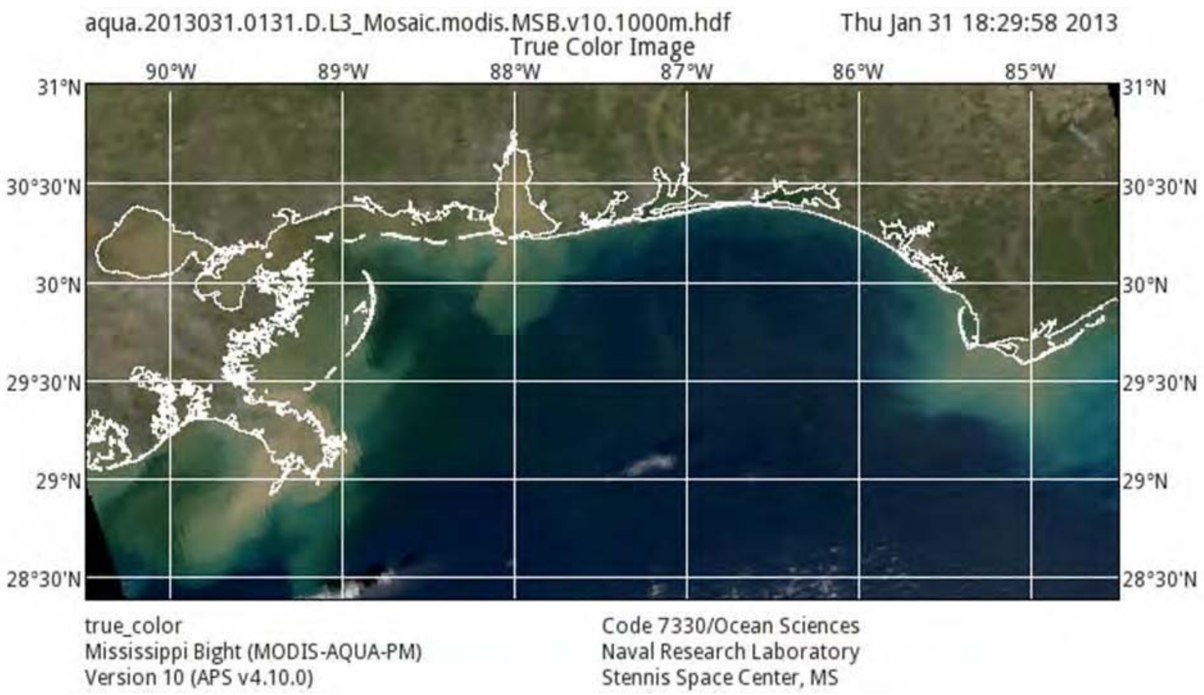

Figure 2: Example of a MODIS Aqua true color image for January 31, 2013 generated using AOPS v4.10

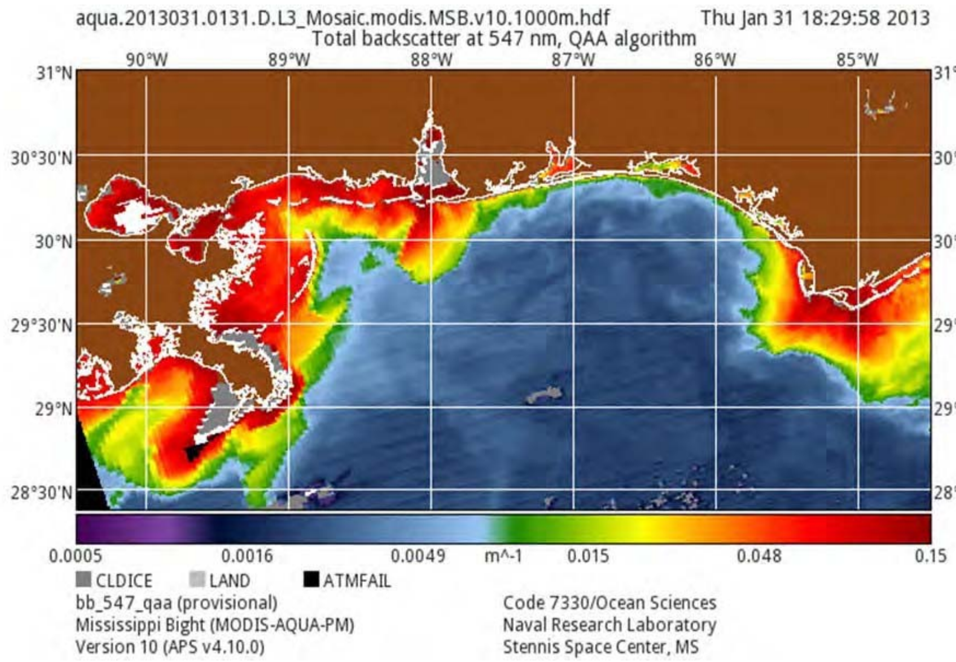

Figure 3: Example of the backscattering optical product at 547nm from AOPS v4.10 (MODIS Aqua, for January 31, 2013). Notice the data holidays (grey pixels) resulting from various remote sensing processing flags, such as failure of the atmospheric correction. Black areas are masked due to atmospheric failure and no coverage.

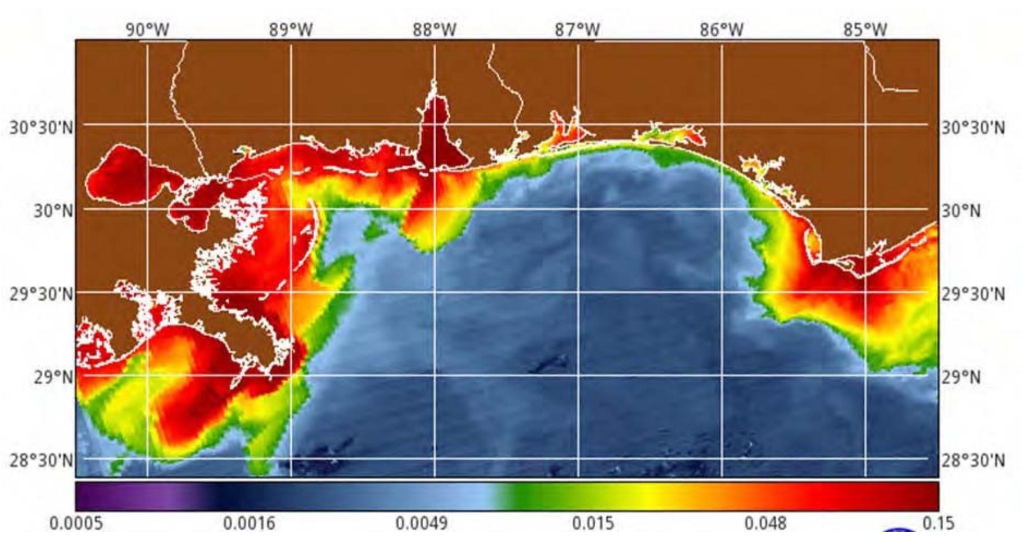

Figure 4: Example of the backscattering at 547nm completely filled seed image (MODIS Aqua, for Jan 31, 2013), all pixels have an assigned bb 547nm value. A filled 'seed' image is a requirement for advection via BioCast.

Seed Image Stages

BioCast is dependent on the creation of a seed image. This image defines the area and is the background for all of the advected products. As BioCast runs, this image goes through different stages correlating to the process flow. The 6 different stages are:

1) Daily Composite (Figure 5)
2) Limited Spatial Interpolation of the Daily Composite (Figure 6)
3) Limited Nearest Neighbor Fill of the Daily Composite (Figure 7)
4) Composite Result of #2 and #3 with Forecast (Figure 8)
5) Limited Spatial Interpolation of the Composite (Figure 9)
6) Nearest Neighbor Fill of the Limited Spatial Interpolation of the Composite (Figure 10)

The following figures are examples of these stages:

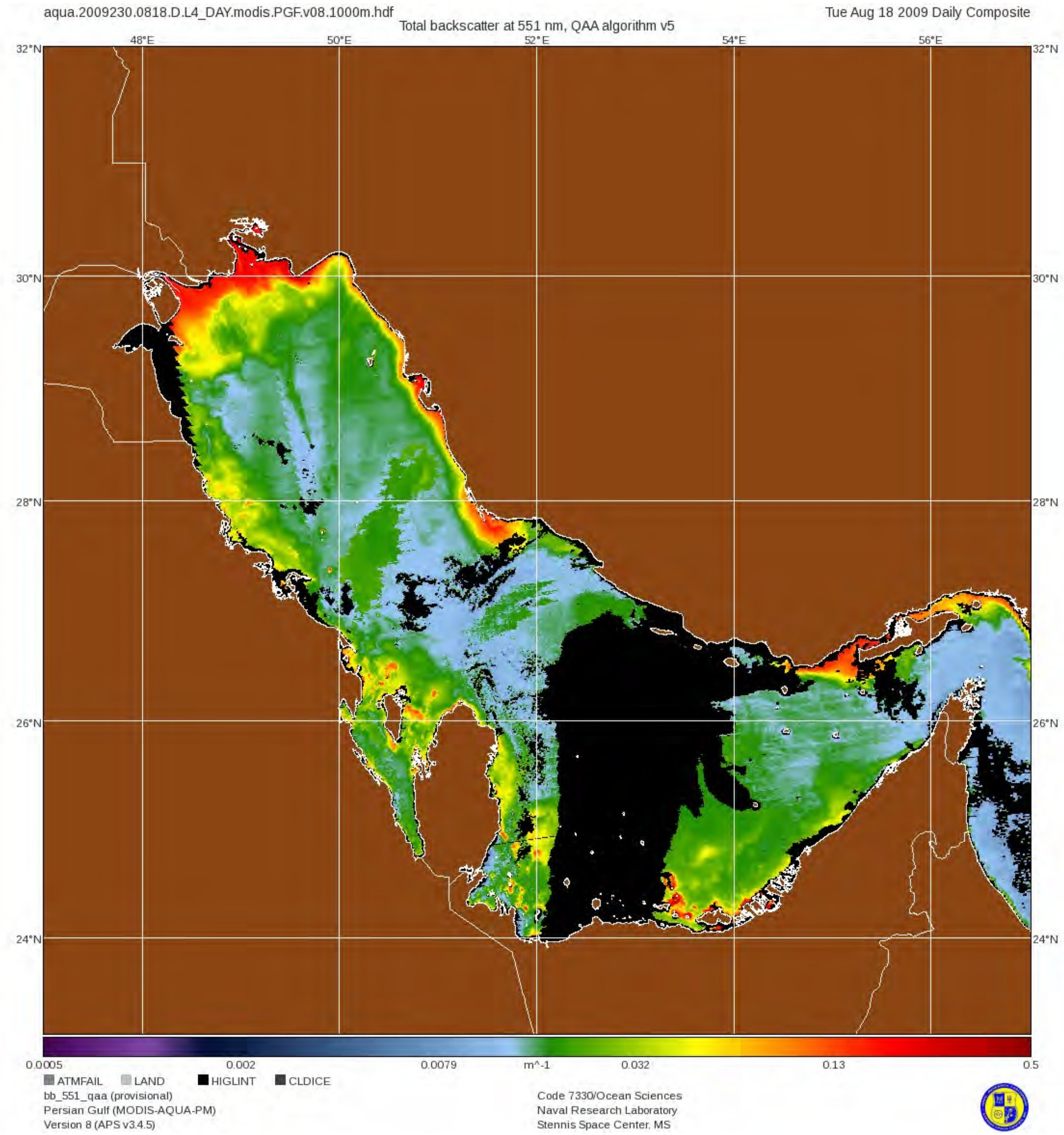

Figure 5: Daily Composite of the Persian Gulf

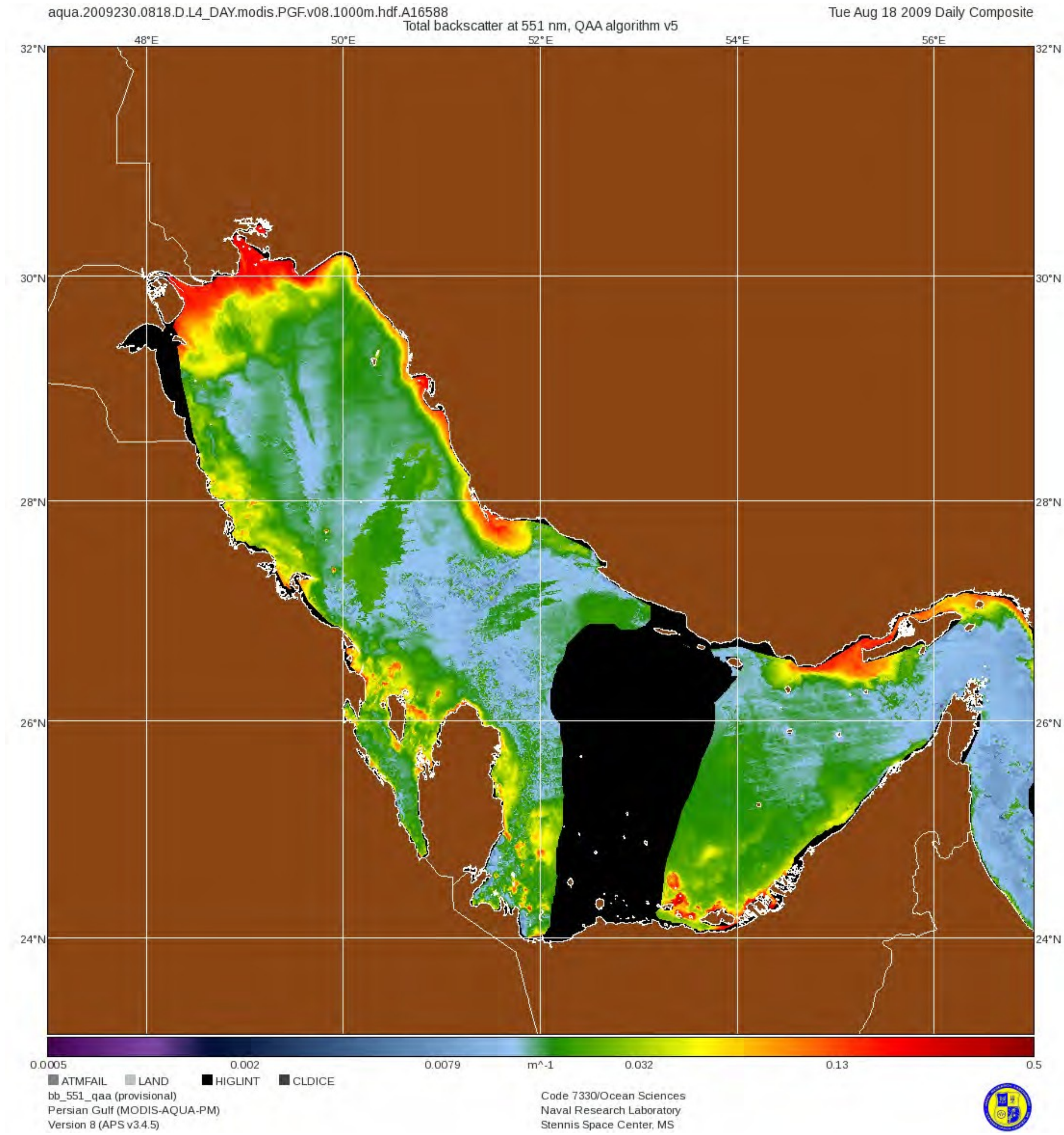

Figure 6: Limited Spatial Interpolation of the Daily Composite

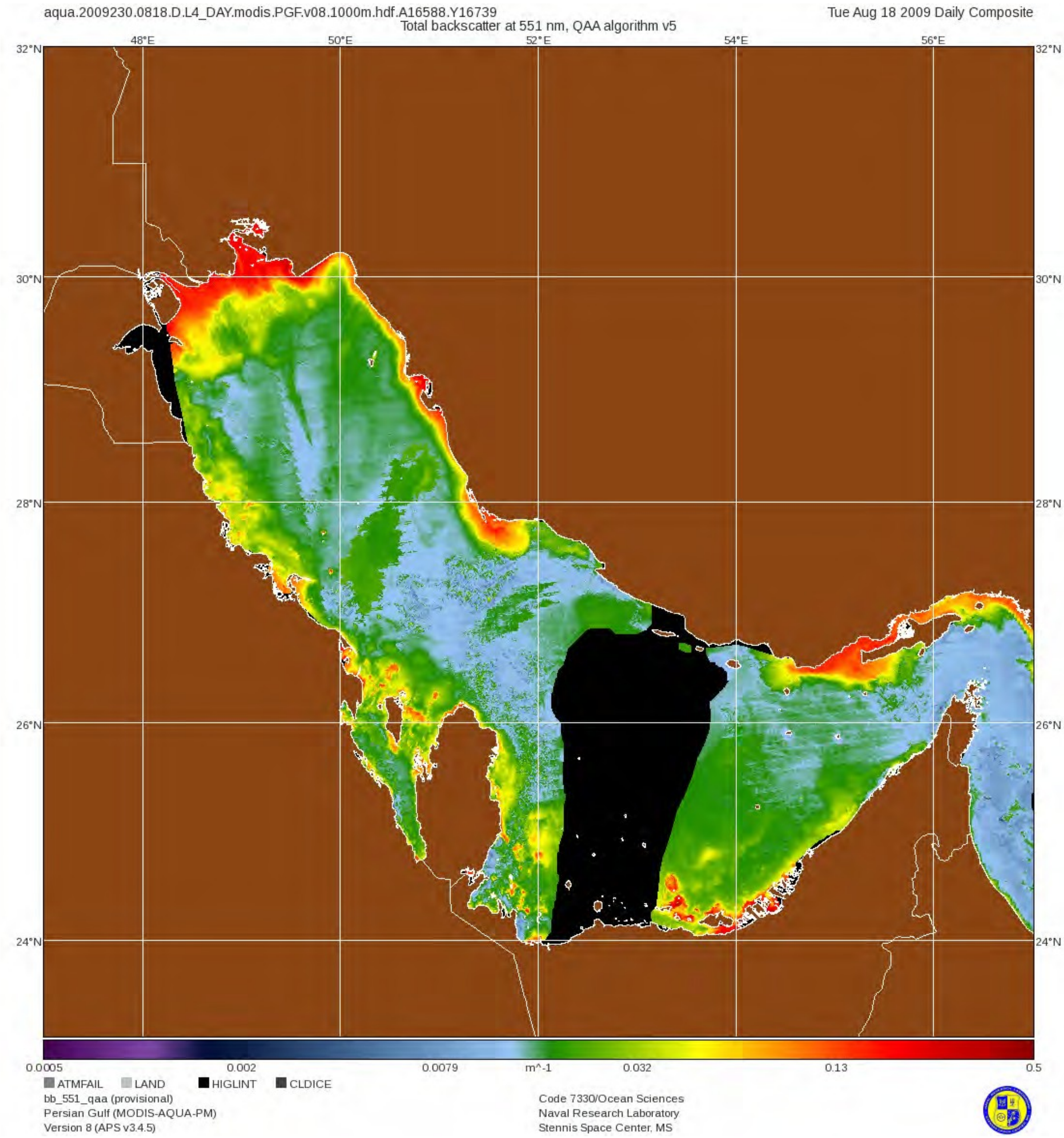

Figure 7: Limited Nearest Neighbor Fill of the Daily Composite

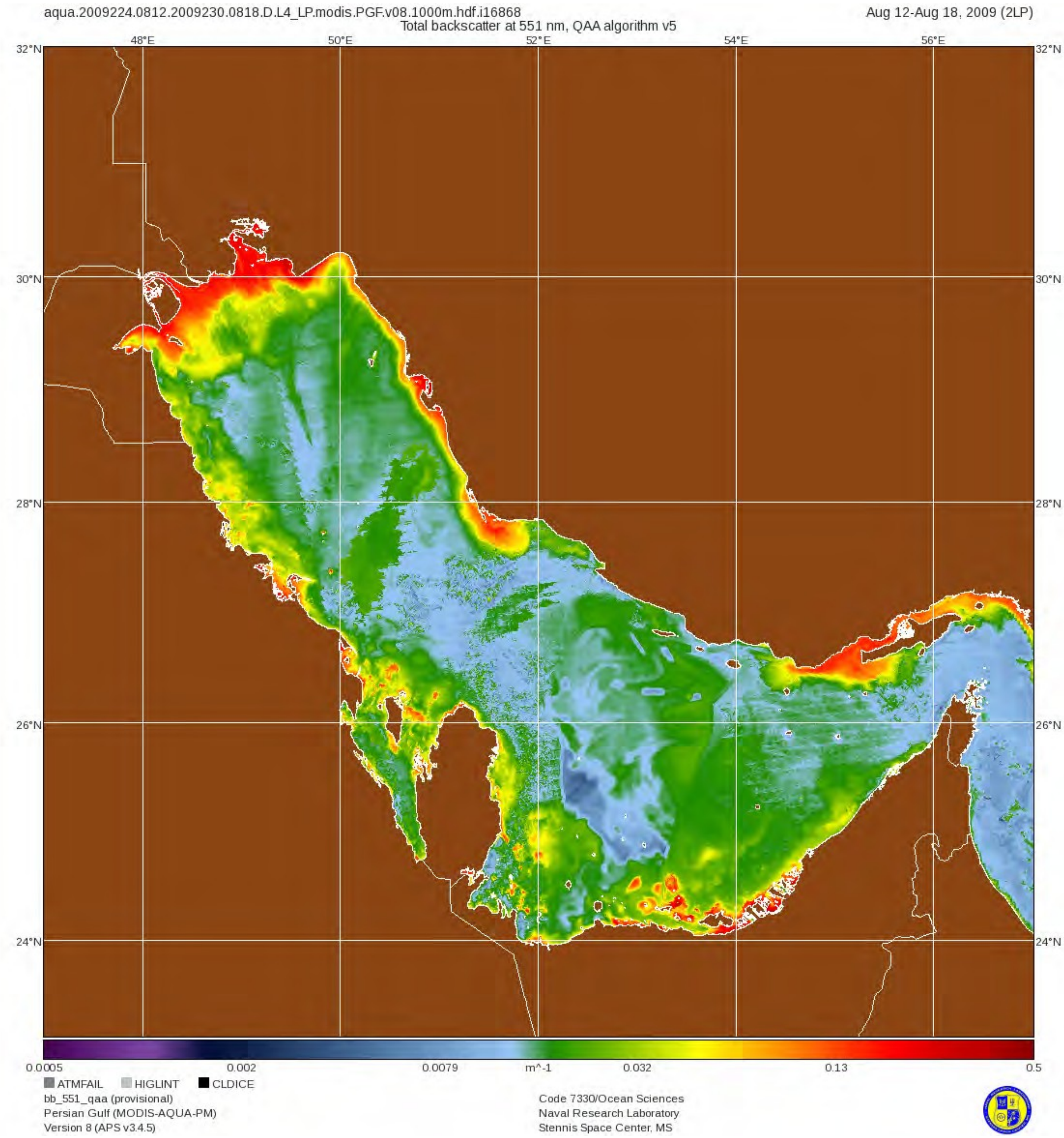

Figure 8: Composite Result of Stage 2 and Stage 3 with Forecast

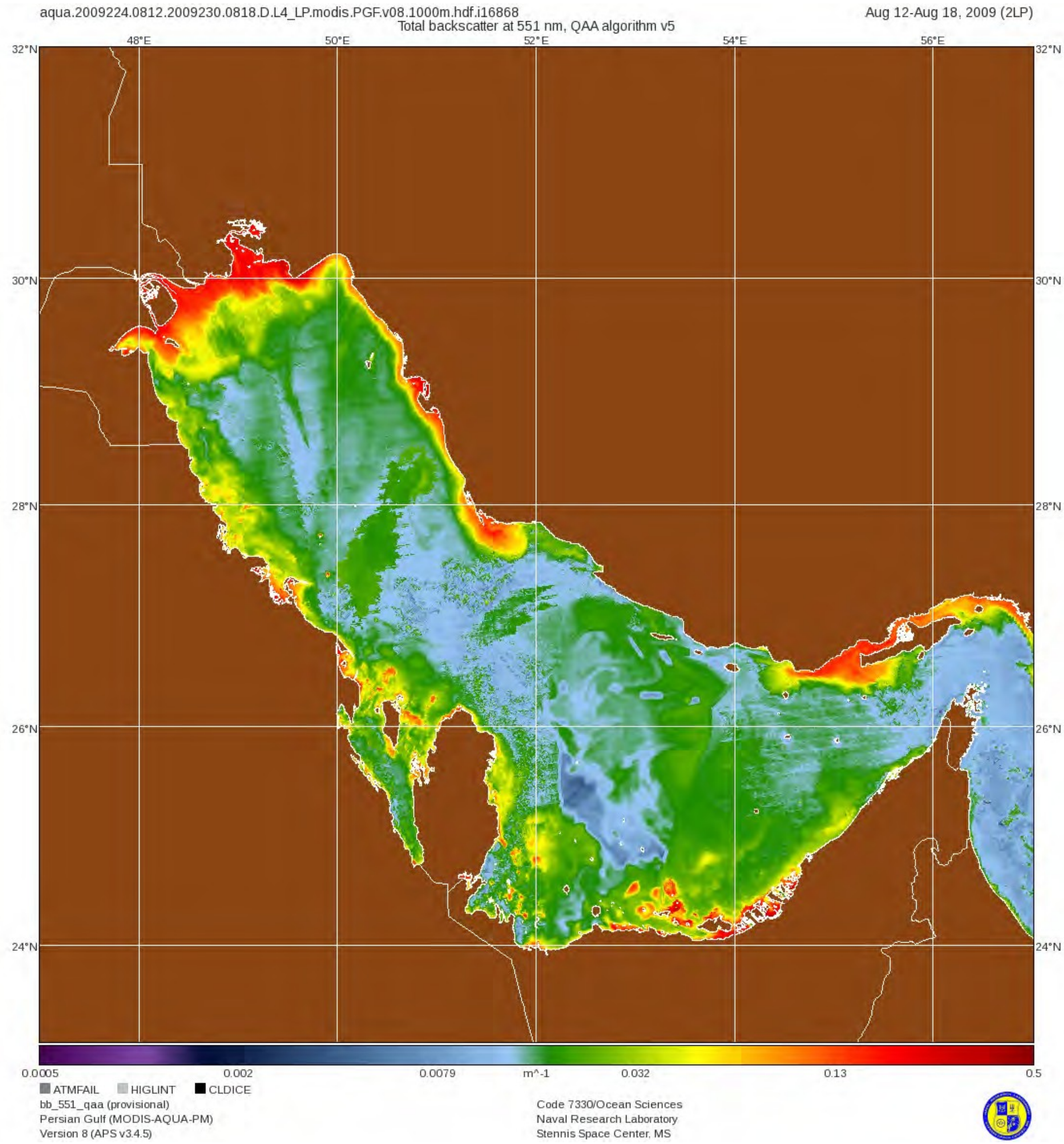

Figure 9: Limited Spatial Interpolation of the Composite Result

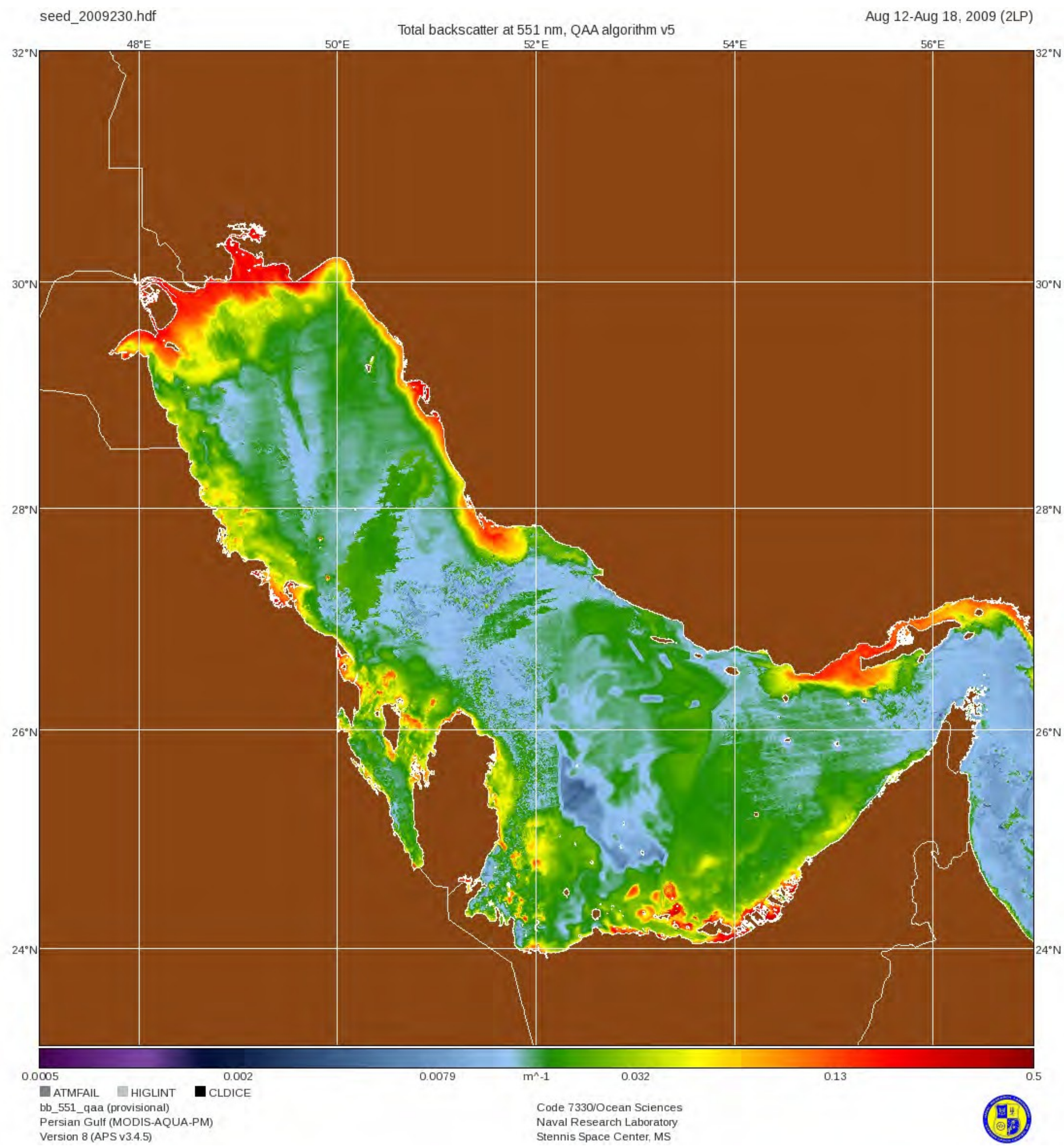

Figure 10: Nearest Neighbor Fill of the Limited Spatial Interpolation

Numerical Models: Relocatable NCOM Current Fields

The physical current field is produced by the Relocatable Navy Coastal Ocean Model (NCOM) and to be represented as '***u***' and '***v***' components in the standard COARDS NetCDF file format (Figure 11, example NCOM data set). The NCOM model is described in *Martin, 2000*. Relocatable NCOM is the relocatable version of the Navy Coastal Ocean Model optimized for limited geographic areas. The spatial grid of the current field is interpolated to match the grid as defined by the AOPS HDF file. The accuracy of the forecast product is dependent on the spatial and temporal resolution of the model fields.

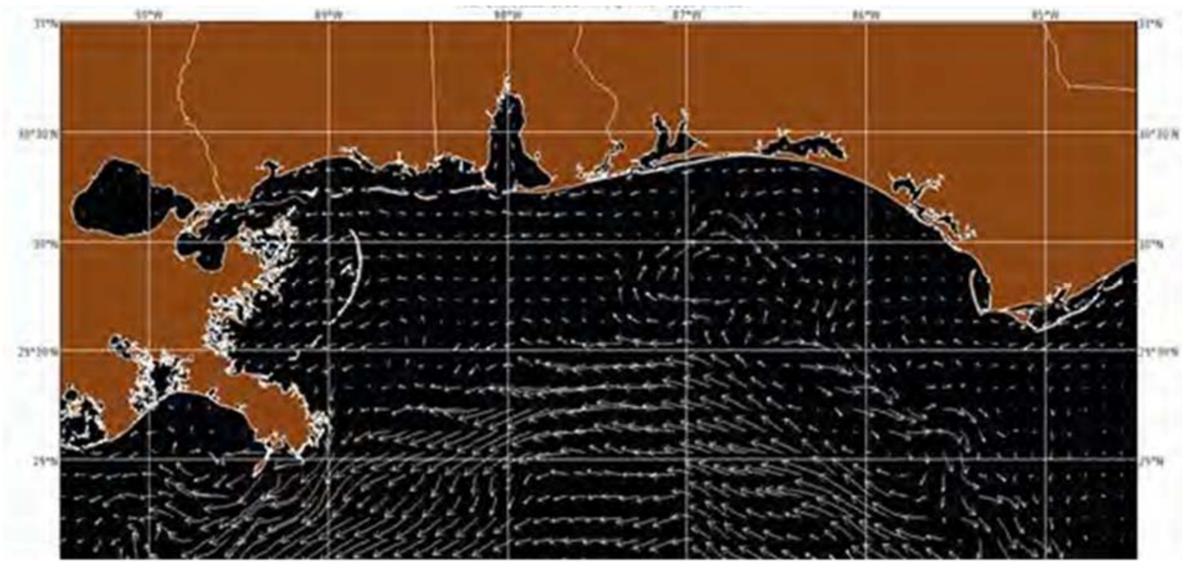

Figure 11: Figure 3. NCOM Surface Current Vectors (u,v)

Data Output

The output of the BioCast system is a set of files in NetCDF format, where one NetCDF file is created for each time step (configurable). The temporal frequency for output may be adjusted to accommodate hourly resolution. The geographic dimensions will match those of the input AOPS HDF file.

Outputs from these transitions will advance and deliver near real time high resolution fused and integrated oceanographic products which can be used to support a variety Navy missions especially MIW, and LIDAR operations. The products include 1) a 2D/3D forecast of coastal ocean optical properties to support performance surface efforts, 2) a performance surface of the laser imaging systems (the AN/AQS-24 performance surface has already been packaged into the TODS system) 3) swimmer performance surface (visibility and vulnerability), 4) performance surface for laser system (eg. ALMDS), and 5) a performance surface for deployment of active and passive EO bathymetry systems (CHARTS).

Important BioCast Caveats and System Limitations

Bathymetry

BioCast uses information from ocean circulation models to describe the three-dimensional transport of optical properties. In this sense, the operational ocean circulation models (such as NCOM and HYCOM) are the "parent" models and BioCast is a "child" model. This is an important conceptual paradigm because if significant changes are made to the physical domain of BioCast (the child) that are very different from the parent, then large errors and/or model failure can occur. For example, three-dimensional ocean current velocities are mapped from the parent model to the child model over the same geographical area. BioCast constrains these velocities to observe continuity, and as a result, conservation of mass. This keeps the optical properties positive-definite and preserves a reasonable forecast solution. If, however, the bathymetry used in BioCast (the child model) is significantly different from the bathymetry used in the parent model, then BioCast may be unable to preserve flow field continuity. This may result in numerical instability and model failure.

Our testing and design of the system suggests small discrepancies in the bathymetry will not cause any significant problems. In fact, several fail-safe mechanisms are built into the numerical code to prevent model failure in the event of small numerical instabilities. However, if a very-high resolution bathymetry is used (to include topographic irregularities) in the child model whereas a low-resolution, coarse (or smoothed) bathymetry was used in the parent model, then the system will likely fail. This is because large changes in the bathymetry will cause accelerations in the fluid flow in order to maintain hydrodynamic continuity. If these irregularities were not accounted for in the parent hydrodynamic model, the child model will be unable to adjust the global velocity fields in a reasonable fashion. The BioCast continuity adjustment is only valid and reasonable for relatively small velocity corrections.

BioCast also creates an identification of "land" points before it executes a forecast cycle. The code must identify "ocean" points adjacent to "land" in order to correctly perform the transport calculations. Any disagreement between the satellite image and the physical ocean model about where land is located will be resolved in favor of land. BioCast assumes that areas of zero motion (component velocities are both equal to zero) are land points. Once a point is identified as land – no transport at that exact location is calculated. This is normally not a problem if the land designation in the parent model and the satellite image are reasonably close. However, the user should be aware that if the satellite identifies (or the parent model) a large region of land not present in the parent model (or satellite) there will be no forecast in those locations.

Horizontal Scaling and Numerical Diffusion

Development and testing of the BioCast system has taken place primarily at horizontal resolutions of approximately 0.5 – 3 km. This is a typical horizontal resolution for regional ocean models as well as satellite ocean color imagery. BioCast utilizes a first-order, upstream numerical material transport scheme. This numerical method contains implicit numerical diffusion. In this case, this implicit diffusion is an advantage of the system: there is no need for explicit diffusive terms, numerical diffusion/turbulence closure schemes, and the associated computational costs. The amount of this implicit numerical diffusion is a function of the velocity, internal time step, and horizontal resolution. Given these variables at typical BioCast application values, and given the aforementioned horizontal resolutions, the BioCast numerical diffusion scales almost perfectly with the magnitude of natural horizontal eddy diffusion observed in the oceans (Obuko, 1970). This is the reason, in a qualitative sense, that the BioCast results also appear to be reasonable to the operator. However, at finer scales of horizontal resolution (~ 50 meters) the BioCast results may appear overly diffusive. Application at these finer scales will require calculation of anti-diffusive numerical fluxes or an alternate numerical transport scheme. It is strongly recommended that BioCast applications stay in the 0.5 – 3 km horizontal scaling range.

The internal time step in BioCast is automatically adjusted to respect the Courant-Freidrichs-Lewy (CFL) stability condition. Once again, given typical ocean current velocities and the recommended horizontal scaling range, the numerical material transport scheme is mass conservative and stable. Outside of the recommended horizontal scaling range, the CFL condition will still be respected but the numerical diffusion may appear as either excessive or inadequate compared to natural or expected rates of horizontal diffusion. It is also important to note that as an additional guarantee of numerical stability, the child model will not recognize and apply any component velocity magnitude in excess of 2 m s^{-1} (the magnitude of component velocities are limited to this value). The present BioCast software is not suited to hydrodynamic regimes where component velocity fluctuations in excess of this magnitude are common.

The GIGO Principle

The initial release of the BioCast software is applicable to any user-defined tracer (satellite product). With this flexibility comes the caveat that there is no additional quality control check on tracer values. The system assumes the tracer is positive-definite (maintains non-zero and positive values across the domain), but there are no additional constraints. If the satellite image contains pixels with excessively high product values compared to the expected product value ranges, BioCast contains no internal quality control mechanisms and this value with be transported within the model. This may lead to spurious results in the forecast cycle. This is the Garbage In – Garbage Out (GIGO) principle. The user is responsible for cognizance of the GIGO principle and quality control of data streams fed into the BioCast system.

Bio-Cast Processing

BioCast processing flow is controlled by a series of cron scripts, as seen in Figure 12. There are several stages to the processing. First, a check is performed to ensure that the necessary data files exist. Then, the seed generation procedure is performed, followed by the conversion of the seed HDF file to NetCDF format. Next, a configuration file is generated and passed to the optical forecast executable to perform the forecast advection. Lastly, the output NetCDF files are moved to the configured output directory, thus allowing the TODS display system to create quick look browse images.

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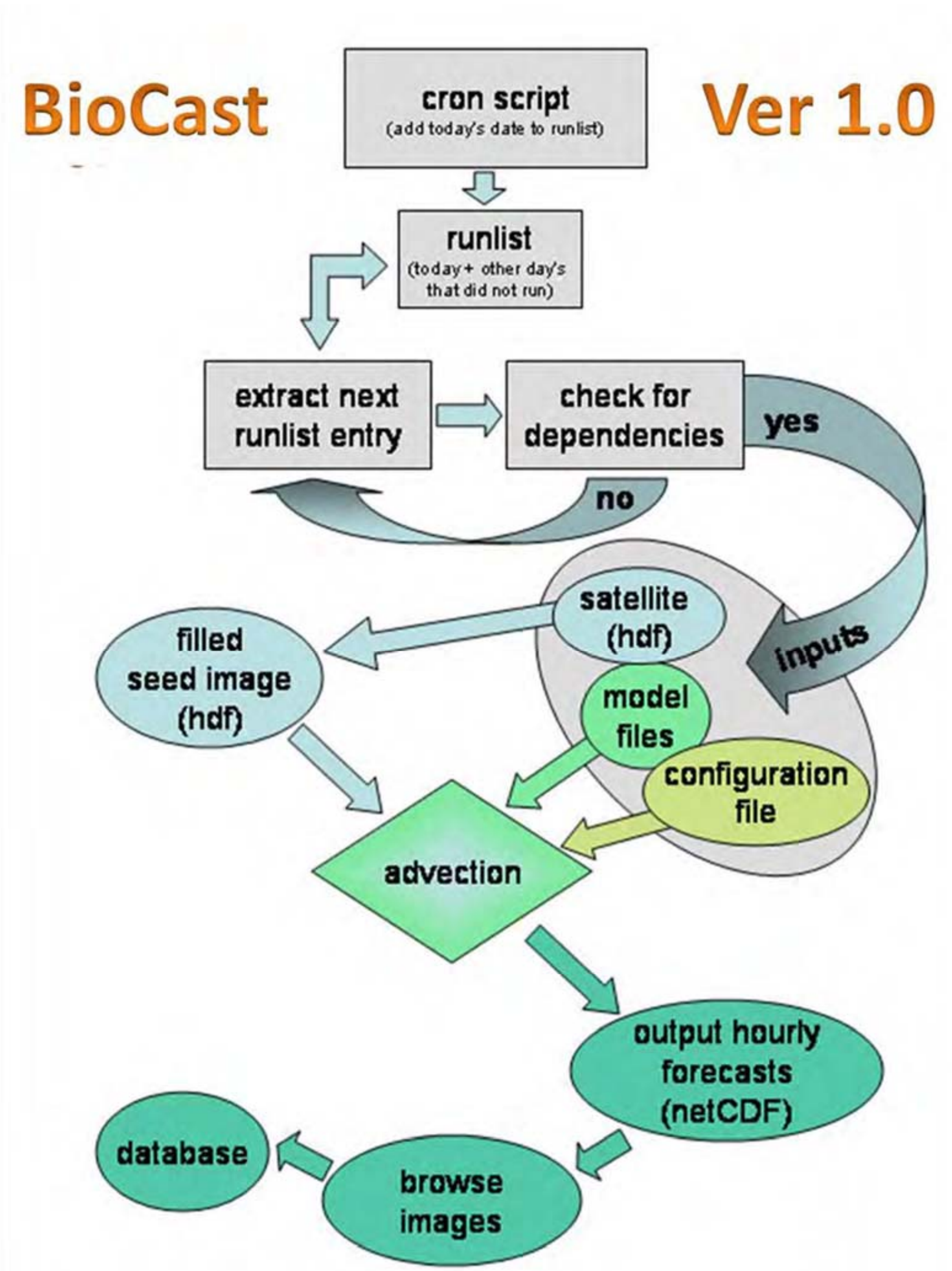


Figure 12: BioCast process flow diagram

The top-level OpCast.sh script searches for the required data files. If it does not find all of the files, it exits with a non-zero status, which notifies the cron.sh script that the particular date entry should not be removed from the run.list file and will try to run again the next time the cron is executed. If it does find all of the files, then it generates a configuration file and feeds it to the forecast program which performs the forecast and produces the results in a series of NetCDF files. After the forecast NetCDF files are produced, quick-look browse images are produced and the files are moved to their configured output directory. Once the procedure has completed successfully, the cron.sh script will remove the date entry from the run.list file.

Grid Space

Bathygen was developed and will be delivered with this version of BioCast. Bathygen allows the user to create a bathymetry file using the AOPS satellite grid/hdf file as input. The bathymetry grid is used as the primary grid for advection (note that the satellite and model grids are the same). If the modeled current fields are on a different grid, they will be interpolated to the primary grid. The boundary of the advection will be limited to the smaller of the two boundaries, satellite grid or model grid, such that advection will not be performed outside of the data boundary. For example, if the satellite imagery fits entirely within the model grid, then every point within the satellite grid will have advection performed on it. If some part of the satellite grid falls outside of the model grid, then that portion of the satellite imagery will not be advected and the grid points will be flagged with the 'invalid' value.

Limitations on Maximum Grid Size: The maximum dimensions of the satellite and model grids are currently hard coded. The satellite grid cannot be larger than 3400 x 3400 and the model grid cannot be larger than 1500 x 1500. Should a requirement to process larger grid sizes arise, the hard coded limits can be raised, and the program recompiled.

Grid Type

Since the software currently makes assumptions about grid cells having a fixed area, and due to the current handling of navigation data, regular grids[5] are required. In addition to a regular grid, the software can handle grids whose navigation in one dimension does not change with respect to the other dimension, such as the Mercator projection.

BioCast Validation

BioCast validation is completed in a six step procedure as described in Figure 13. Today's image (of any optical product, this example shows c 531nm) is obtained from the satellite. An initialization field is created, filling in gaps in coverage as required by the forecast model. This optical data initialization field is input into BioCast with the NCOM model forecast. BioCast advects the bio-optical property with respect to the predicted currents and ADR to produce a 24 hour forecast. The forecast is then compared to the data derived from the next day's image, and a difference field is generated highlighting the difference between the measured and forecast property. Statistics are generated providing metrics for analysis. The complete BioCast validation can be seen in "Validation Test Report for the BioCast Optical Forecast Model Version 1.0."

[5] A pure regular grid is one in which the units of navigation increase by a fixed amount between each grid cell, sometimes referred to as equal-rectangular grid.

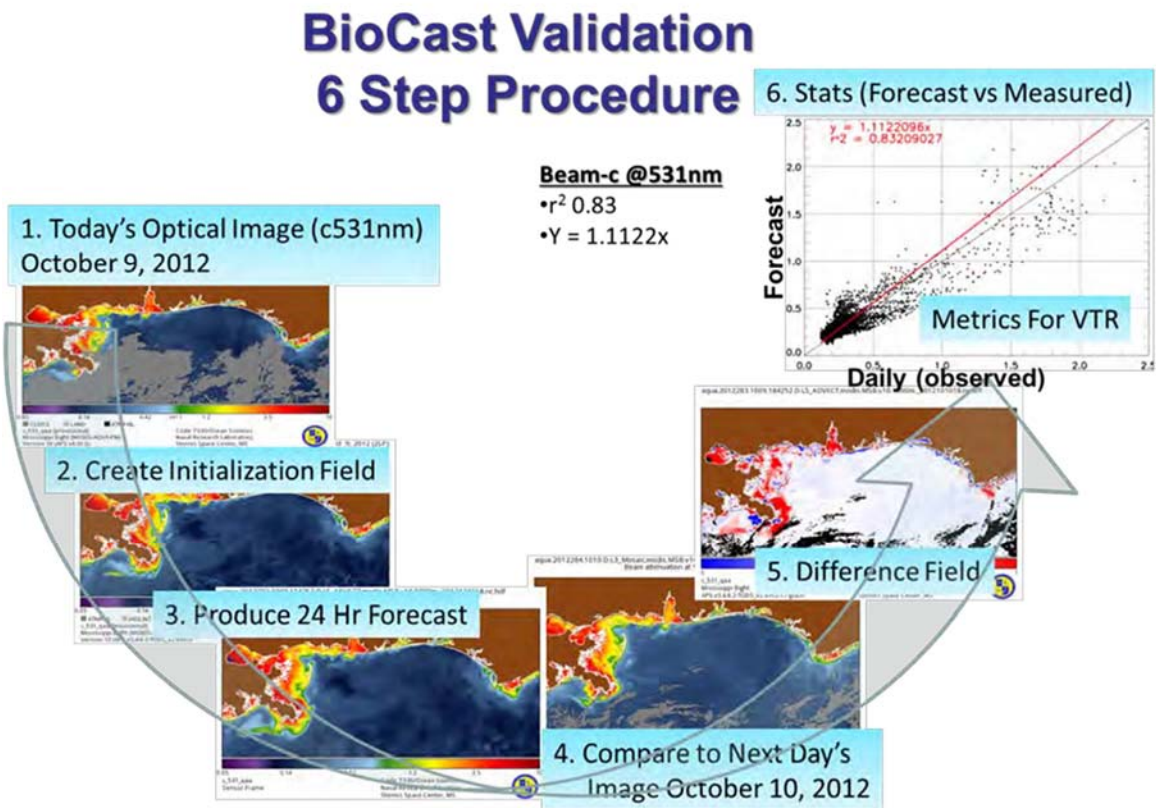


Figure 13: BioCast Validation procedure. Today's image (of any product, shown here is c 531nm) is obtained from the satellite. An initialization field is created, filling in gaps in coverage. The optical data initialization field is input into BioCast with the NCOM model forecast. BioCast advects the bio-optical property with respect to the predicted currents and ADR to produce a 24 hour forecast. This forecast is then compared to the data derived from the next day's image and a difference field is generated showing the difference between the measured and forecast. Statistics are generated providing metrics for analysis.

Installation and Setup

The system installation organizes the binaries, scripts, system configuration, and area configuration into separate directories. These directories include areas, bin, data, docs, logs, and scripts. The 'areas' directory contains a sub-directory for each area that will be processed. The 'bin' directory contains the executable binaries BioCast uses to read and create files. The 'data' directory is needed by APS for the image creation portion. The remaining directories are self-explanatory; 'docs' is the BioCast documentation, 'logs' holds all of the log files, and 'scripts' is the BioCast source files.

Components

The BioCast System is composed of a set of scripts which are in charge of searching for the necessary input fields and generating configuration files. These scripts make calls to a set of binary programs that are installed with the system as well as standard binaries expected to be installed on the system. The following software components are required:

System

- Bash
- Perl
- Nctools
- ImageMagick

NRL Provided

- arnone2DConv_Linux (C++ program)
- libarnone2DConvNETCDF_Linux.so
- libarnone2DConvHDF_Linux.so
- HDFConvert-2D (bash script)
- Sat_Forecast_Model (Fortran program)
- ncreform (C program)
- hdf (C program)
- imgMean (C program)
- imgFillGaps (C program)
- imgCoards (C program)
- gregor (C program)
- (region).sh (Bash script)
- (region).cron (Bash script)
- update_listfile.sh (Bash script)
- runlist (Perl script)
- ParticleFuncs.sh (bash script)
- make_merged_funcs.sh (bash script)
- make_merged_image.sh (bash script)
- make_merged_product.sh (bash script)
- make_seed_cron.sh (bash script)
- makeXVisionSeed.sh (bash script)
- BioCast_cron.sh (bash script)
- BioCast.sh (bash script)
- runlistmaker.sh (bash script)

Configuration

Each area should contain three files named cron.sh, BioCast_cron.sh, and BioCast.sh. Other files like run.list and run.log will be created while BioCast runs. These files configure BioCast and tell the system where to look for files and how to get what it needs to create the forecast. Based on the configuration and user settings, the cron script is the master script that calls all of the other scripts and sets up the environment variables BioCast needs. So to configure BioCast, create a directory under the 'areas' directory and place a cron.sh script in this directory which should look like Example 1: cron.sh.

```
>>cd /BioCast/areas/
>>mkdir PersianGulf
```

```
>>cd PersianGulf
>>vi cron.sh
```

Example 1: cron.sh

```
#!/bin/sh
# Main cron script

toplevel='/projects/opsupport/BioCast'
scripts_dir="$toplevel/scripts"
areas_dir="$toplevel/areas"

this_area_dir="$areas_dir/PersianGulf"

update_runlist_sh="$scripts_dir/update_listfile.sh"
runlist_sh="$scripts_dir/runlist"

runlist="$this_area_dir/run.list"
script_cmd="$this_area_dir/BioCast_cron.sh"

export LOGFILE="$this_area_dir/run.log"

export UPDATE_RUNLIST="NO"
export UPDATE_DAYS="1"
export UPDATE_OFFSET="-1"

$update_runlist_sh $runlist
$runlist_sh -p $script_cmd $runlist
```

As shown, the cron.sh sets the environment variables and calls the scripts to generate a list of dates for product creation (run.list). The next script to be set up for a particular area is the BioCast_cron.sh. This Bash script creates the file name and calls the BioCast.sh script.

Example 2: OpCast_cron.sh

```
#!/bin/sh

#
# Cron helper script
#
# This script may be called with the appropriate arguments to
# reproduce what the cron job would produce.

toplevel='/projects/opsupport/BioCast'
scripts_dir="$toplevel/../TODS_scripts"
areas_dir="$toplevel/areas"

this_area_dir="$areas_dir/PersianGulf"

make_cron_sh="$scripts_dir/BioCast_cron.sh"
export MAKE_MERGED_FUNCS_SH="$scripts_dir/make_merged_funcs.sh"
export PARTICLE_FUNCS_SH="$scripts_dir/ParticleFuncs.sh"

# Export make_merged_cron_sh environment variables
#export
OUTPUT_DIR="/projects/reason/rs/lvl5/3DField/1.28/modis/RIMPAC08"
export APS_NOMENCLATURE='1'
```

```
export RSDIR='/rs'
export SENSOR='modis'
#APSVER='5.4'
export REGION='PersianGulf'
export APS_DAYNIGHT='D'
export SPRE='aqua'
export STATIONCODE='v08.1000m'
export REGEXT='PGF'
export MAKE_MERGED_PRODUCT="$this_area_dir/BioCast.sh"

# Due to IDL, we must cd to the directory that the
# sav file is in so that our XML config file we be there too.
cd "$this_area_dir" || ( echo "Failed changing to $this_area_dir" &&
exit 1 )

exec "$make_cron_sh" "$@"
```

The BioCast.sh script is the main configuration script and finishes defining all of the environment variables necessary to begin merging products and creating the forecasts. It accepts a year and day-of-year as arguments. When it is called, it will create the forecast based on its arguments, but it will place the products in the current directory, which can be useful for testing.

Example 3: OpCast.sh

```
#!/bin/sh
#
# helper script to set up environment for call to
make_merged_product.sh
#
# This script can be called stand-alone to reproduce the requested
product.


make_merged_product_sh='/projects/opsupport/TODS_scripts/BioCast.sh'

export PARAMS_FILE='fcst.inp'

#export SPRE='SMODPMMER'
#export SENSOR='seawifs-aqua-meris'
#export FILETYPE=".L4_LP"
#export STATIONCODE='_NOAA'
#export STATIONCODE=
#export REGEXT='PGF'
#export REGION='PersianGulf' APSVER='1.0'
#export COMPDIR="/rs/lvl4/$SENSOR/$APSVER/$REGION/7daylp"
#export APS_LEVEL='L4_LP'
#export

export APS_NOMENCLATURE='1'
export SPRE='aqua'
export SENSOR='modis'
export STATIONCODE='v08.1000m'
export REGEXT='PGF'
export REGION='PersianGulf'
export APS_DAYNIGHT='D'
```

```
#export APSVER='current'
#export COMPDIR="/projects/reason/rs/lvl4/$SENSOR/$APSVER/$REGION/seed"
export COMPDIR="/rs/lvl4/$SENSOR/$REGION/seed"
export APS_LEVEL='L4_LPA'

export MODEL_SOURCE='CLARK'
export MODEL_DIR='/projects/opsupport/RELO/areas/persiangulf'
export MODEL_REGION='ncom_relo_pg2_app1'
export MODEL_MODEL=
export MODEL_DOMAIN=
export MODEL_EXPERIMENT=
export MODEL_NEST=

#export MODEL_SOURCE='RELO'
#export MODEL_DIR='/projects/opsupport/TODS/test_data/dvd/090611_1439'
#export MODEL_REGION='ncom_relo_arabian_miw'
#export MODEL_MODEL=
#export MODEL_DOMAIN=
#export MODEL_EXPERIMENT=
#export MODEL_NEST=
export MODEL_MAX_TIME_STEP=
export MODEL_MAX_TIME_DIFF=
export MODEL_TIMESTEP='1'

# Currently this can be mld imld ucurr or vcurr
export MODEL_PRODUCTS='water_u water_v'

# Name for file name purposes
#export u3dVarName='U_Velocity'
#export v3dVarName='V_Velocity'
#export mldName='mld'
#export imldName='mdg'
#export ucurrName='u3d'
#export vcurrName='v3d'

# Variable name within the file
#export mldVarName=$mldName
#export imldVarName=$imldName
#export ucurrVarName=$ucurrName
#export vcurrVarName=$vcurrName

export FORECAST_HOURS='36'
export FORECAST_TIMESTEP='1' #cannot be less than  the MODEL_TIMESTEP
export FORECAST_SATPRODS='chl_oc3,bb_551_qaa,Kd_490,Zeu_lee'

export HDFCONVERT_OPTS='-fliplats'

#export PROGRAM='/projects/opsupport/BioCast/bin/Sat_Forecast_Model'
export PROGRAM='/home/casey/projects/fcst-2/Sat_Forecast_Model'


exec "$make_merged_product_sh" "$@"
```

The other files located in an areas subdirectory include the run.log and run.list files. These files are created by the system. The run.log file is a simple log that is appended to during each

processing run and contains details about the run. Any errors can be found in the log file. The run.list file contains a list of dates that require processing. This file may be edited manually if desired, but is generally updated automatically whenever cron.sh is run.
The cron.sh file can be called manually from the command line or more commonly, it is called from a top-level cron job. Define this by using the following on the server.

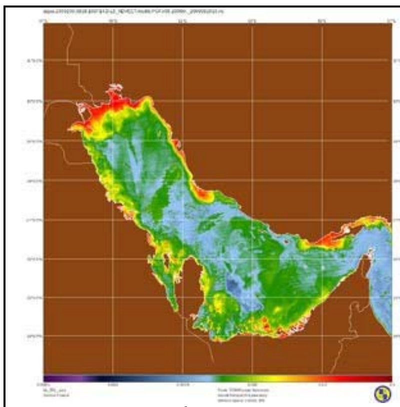
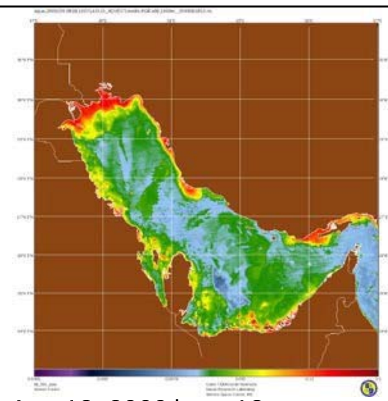
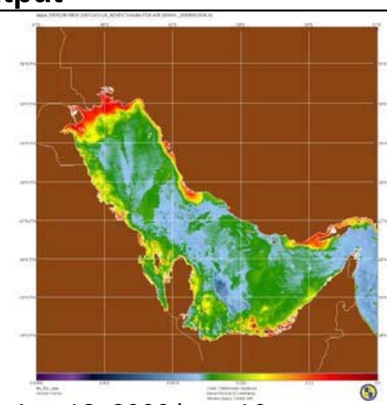
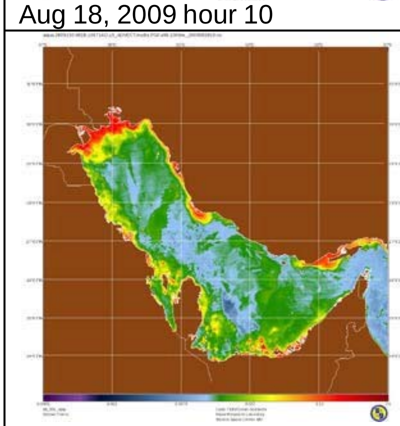
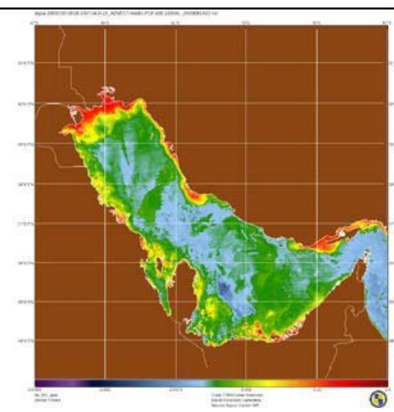
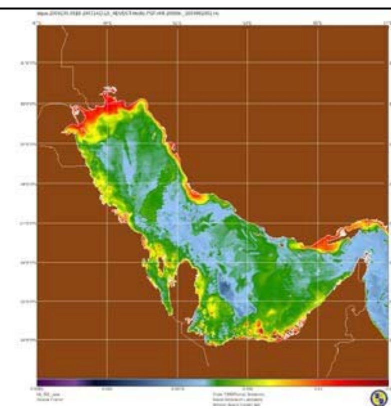
```
>>crontab –e
```

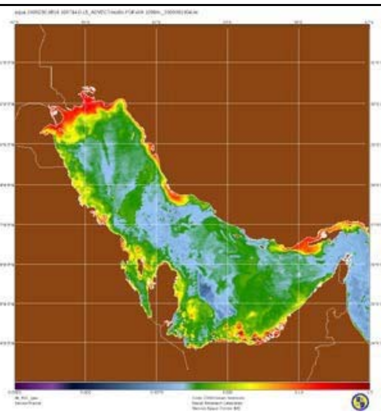
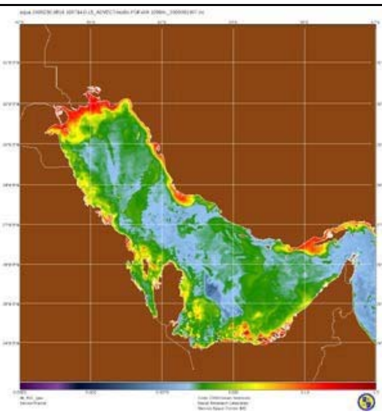
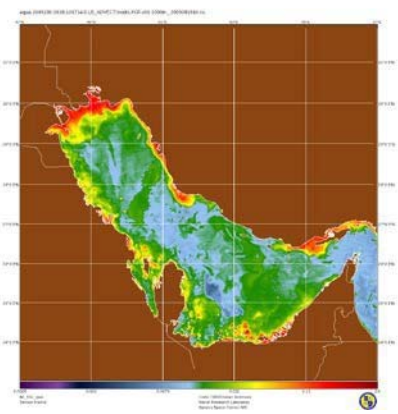
The number of times it needs to run is dependent on the amount of data. NRL runs it once per day, but if data is steadily coming in, it's run more often. The cron will process the run.list file and produce the forecast for each entry in the file. When it is finished, the only remaining entries in the run.list file will be those which have not processed successfully. The BioCast.sh script is designed so that it can be run manually to produce its results in the current directory for testing and debugging. The BioCast.sh script is used to configure the environment variables specific to each region that allow the generic processing scripts to find the data files required to run the region and manage the resulting BioCast products. Once the directories, cronjobs, and scripts are setup, installation is complete.
** Additional variables and settings can be seen in the Appendix **

BioCast Outputs

Example forecasting results of BioCast can be seen in Table 1 and Figure 14.

Table 1: Persian Gulf BioCast Output

 Aug 18, 2009 hour 10	 Aug 18, 2009 hour 13	 Aug 18, 2009 hour 16
 Aug 18, 2009 hour 19	 Aug 18, 2009 hour 22	 Aug 19, 2009 hour 1

 Aug 19, 2009 hour 4	 Aug 19, 2009 hour 7	 Aug 19, 2009 hour 10

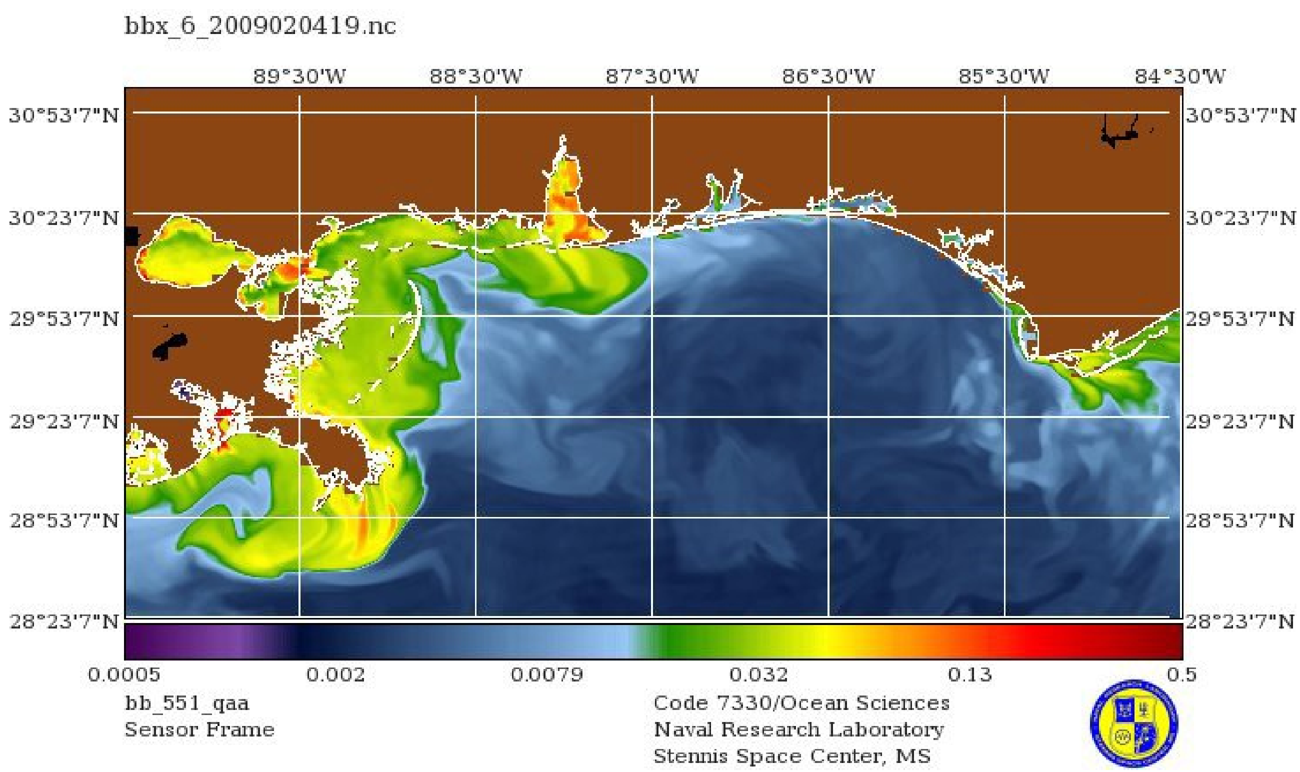


Figure 14: Six hour forecast of MODIS Aqua backscattering at 551 nm

Outputs from the advection software are user-defined hourly forecasts of the desired satellite product written out to netCDF files inheriting the grid and resolution of the satellite product. Quick-look browse images are produced and the files are moved to their configured output directory.

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Appendix A

****NOTE** Variable and path names use "APS" syntax, rather than "AOPS"**

Areas Scripts Variables

cron.sh

VARIABLE NAME	DEFAULT VALUE	OPTIONS	NOTE
TODS_DIR	/projects/opsupport/OpCast		
toplevel	$TODS_DIR		
scripts_dir	$toplevel/scripts		
areas_dir	$toplevel/areas		
this_area_dir	$areas_dir/AREA_NAME	replace AREA_NAME with your current area, such as MissBight_BioCast2	
update_runlist_sh	$scripts_dir/update_listfile.sh		
runlist_sh	$scripts_dir/runlist		
runlist	$this_area_dir/run.list		
scripts_cmd	$this_area_dir/opcast_cron.sh		
LOGFILE	$this_area_dir/run.log		
UPDATE_RUNLIST	NO		
UPDATE_DAYS	1		
UPDATE_OFFSET	-1		

opcast_cron.sh

VARIABLE NAME	DEFAULT VALUE	OPTIONS	NOTE
TODS_DIR	/projects/opsupport/OpCast		same as cron.sh
toplevel	$TODS_DIR		same as cron.sh
scripts_dir	$toplevel/scripts		same as cron.sh
areas_dir	$toplevel/areas		same as cron.sh
this_area_dir	$areas_dir/AREA_NAME	replace AREA_NAME with your current area, such as MissBight_BioCast2	same as cron.sh
make_cron_sh	$scripts_dir/opcast_cron.sh		
APS_NOMENCLATURE	1		
RSDIR	/rs		

SENSOR	modis		
REGION	AREA_NAME	replace AREA_NAME with your current area, such as MissBight	
MODEL_REGION	biocast_ncom_relo_amseas_u		
APS_DAYNIGHT	D		
SPRE	aqua		
STATIONCODE	v10.1000m		
REGEXT	COD	replace COD with a three letter code describing your area, such as MSB	
MAKE_MERGED_PRODUCT	$this_area_dir/OpCast.sh		

OpCast.sh

VARIABLE NAME	DEFAULT VALUE	OPTIONS	NOTE
TODS_DIR	/projects/opsupport/OpCast		same as cron.sh and opcast_cron.sh
make_merged_produ ct_sh	$TODS_DIR/scripts/OpCast.s h		
APS_NOMENCLATUR E	0	List of other options include: 1	same as opcast_cron.sh, default set in scripts_dir/OpC ast.sh
SPRE	aqua		same as opcast_cron.sh
SENSOR	modis		same as opcast_cron.sh
STATIONCODE	v10.1000m		same as opcast_cron.sh
REGEXT	COD	replace COD with a three letter code describing your area, such as MSB	same as opcast_cron.sh
REGION	AREA_NAME	replace AREA_NAME with your current area, such as MissBight	same as opcast_cron.sh
APS_DAYNIGHT	D		same as opcast_cron.sh
COMPDIR	/rs/lvl4/$SENSOR/$REGION/ seed /biocast_ncom_relo_amseas _u		
APS_LEVEL	L*	List of other options include: L4_LPA	default set in scripts_dir/OpC ast.sh
MODEL_SOURCE	RELO	List of other options include: CLARK, NCOM, GLOBAL, SERGIO, SHELLEY, NAVO	
MODEL_DIR	/projects/relo/amseas		
MODEL_REGION	ncom_relo_amseas_u		

MODEL_MODEL			
MODEL_DOMAIN			
MODEL_EXPERIMENT			
MODEL_NEST			
MODEL_MAX_TIME_STEP			
MODEL_MAX_TIME_DIFF			
MODEL_TIMESTEP	3		
MODEL_PRODUCTS	water_u water_v		
FORECAST_HOURS	48		default set in scripts_dir/OpCast.sh
FORECAST_TIMESTEP	6		default set in scripts_dir/OpCast.sh
FORECAST_SUBSECTION	0.,0.,0.,0.		default set in scripts_dir/OpCast.sh
FORECAST_SATPRODS	bb_551_qaa	See Appendix A for list of other products	default set in scripts_dir/OpCast.sh
FORECAST_UNAME	U_Velocity	List of other options include: water_u	default set in scripts_dir/OpCast.sh
FORECAST_VNAME	V_Velocity	List of other options include: water_v	
HDFCONVERT_OPTS	-fliplats		
PROGRAM	/projects/opsupport/OpCast/bin/biocast2v3.2		
alt_runlist	/projects/opsupport/OpCast/areas/AREA_NAME_BioCast2_seed/run.list	replace AREA_NAME with your current area, such as MissBight	
browse_dir	BROWSE_DIR	replace BROWSE_DIR with a path where imagery will be saved	
browse_format	png		
chl_oc3_OPTS	-r 0.01,45 –flog10		
bb_531_qaa_OPTS	-r 0.0005,0.15 –flog10		
c_531_qaa_OPTS	-r 0.05,10.0 –flog10		
IMGBROWSE_OPTS	OPTIONS	replace OPTIONS with imgBrowse options, such as including a land mask: -l file=/home/aps/aps_v3.8/etc/landmask/w_MissBight_msk.img	
IMGBROWSE	$APSHOME/bin/imgBrowse		path for imgBrowse executable, default

			$APSHOME and IMGBROWSE set in scripts_dir/make_merged_funcs.sh
APS_DATA	/projects/opsupport/TODS/data		

Hidden Scripts Variables and Options

OpCast.sh

VARIABLE NAME	DEFAULT VALUE	OPTIONS	NOTE
fcst_file	fcst.ing		uses PARAMS_FILE if set
HDFCONVERT	$TODS_DIR/bin/HDFConvert-2D		

make_merged_funcs.sh

APSHOME	$TODS_DIR		
APS_DATA	$APS_DATA/data		
HDF	$APSHOME/bin/hdf		
NCKS	$TODS_DIR/bin/ncks		
NCRENAME	$TODS_DIR/bin/ncrename		
NCREFORM	$APSHOME/bin/ncreform		
GUNZIP	gunzip		
USING_FORECAST_FILE	0		
SPECTRUM_SOURCE	APS_SPECTRUM	List of other options include: NCOM_SPECTRUM, GLOBAL_SPECTRUM, SERGIO_SPECTRUM, SHELLEY_SPECTRUM, CLARK_SPECTRUM, PARTICLE_SPECTRUM, NAVO_SPECTRUM, RELO_SPECTRUM	
SPECTRUM_PRODUCT	chl_oc3m		
vector_type	ncom		
NAVO_DIR			
NAVO_MODEL			
NAVO_REGION			
NAVO_NEST			
NAVO_VECTORPRODS			
NAVO_CONTOURPRODS			
NAVO_MAX_TIME_STEP			
NAVO_MAX_TIME_DIFF	24		
NCOM_DIR			
NCOM_VECTORPRODS			
NCOM_CONTOURPRODS			

NCOM_MAX_TIME_STEP	3		
NCOM_MAX_TIME_DIFF	24		
GLOBAL_DIR			
GLOBAL_REGION			
GLOBAL_MODEL			
GLOBAL_DOMAIN			
GLOBAL_EXPERIMENT			
GLOBAL_VECTORPRODS			
GLOBAL_CONTOURPRODS			
GLOBAL_MAX_TIME_DIFF	24		
PARTICLE_DIR			

Appendix B: From Arnone and Parsons 2004 : Table 4

Table 2 – Common bio-optical and satellite-derived ocean properties from SeaWiFS, and MODIS (Terra and Aqua).

Validated products

Chlorophyll concentration	- biological processes such as algal (harmful and non-harmful) blooms and decay
Spectral backscattering coefficient $bb_{(t\lambda)}$	- 90 to 180 degree particle scattering linked to concentration, composition, index of refraction of organic (marine) and inorganic (terrigenous) particles, resuspension
Spectral absorption coefficient $a_{(t\lambda)}$	- total absorption, changes in water quality
Spectral absorption colored dissolved organic matter $a_{(CDOM\lambda)}$	- conservative tracer of river plumes, linked with coastal salinity, photo-oxidation processes
Spectral particle absorption coefficient $a_{(p\lambda)}$	- particle composition, (organic and inorganic particles)
Spectral phytoplankton absorption coefficient $a_{(\varphi\lambda)}$	- absorption linked to differences in chlorophyll packaging within phytoplankton cells
Remote sensing reflectance $RRS_{(\lambda)}$	- spectral absolute water color and water signature
Diffuse attenuation coefficient (k532, k490)	- light penetration depth, light availability at depth
Aerosol concentration –Epsilon	- type and distribution, affects visibility, Atmospheric correction methods
Beam attenuation coefficient - $c_{(\lambda)}$	- total light attenuation using a collimated beam
Diver visibility	- horizontal visibility, average target size, target contrast, solar overhead illumination
Laser penetration	- underwater performance of lasers (imaging or bathymetry systems)
Sea surface temperature	- skin temperature / bulk temperature (MODIS)

Exploratory products

Surface Salinity	- from absorption at 412 nm or CDOM absorption in coastal areas with high surface gradients (~2).
Particle size distribution (junge distribution) (<1 um - >100 um) and concentration	- from the spectral backscattering coefficient in coastal waters, concentration at different sizes (Haltrin and Arnone, 2003)
Particulate Organic Matter (POM)	- from a(detritus) @443nm), and used to estimate the carbon flux
Particulate Inorganic Matter (PIM)	- from the a(detritus @ 412 nm), and used to estimate particle flux
Total Particle Concentration	- from particle composition, (organic / inorganic particles) regional dependent
Particle organic / inorganic ratio	- particle fluxes in surface water, and settling resuspension

for each size class	
Satellite water mass optical classification	- identification of specific water masses using optical signature and tracking movements
Satellite products integrated with numerical models of currents	- interpreting how the physical processes (advection) affect the bio-optical response (e.g., advection of chlorophyll blooms)
Vertical profiles of bio-optical properties	- determined by assimilating modeled mixed layer depth with the satellite surface chlorophyll
Primary Production	- determined through linked with seasonal SST and chlorophyll fluorescence